Robots that Dive, Hop, Crawl & Fly

Alberto Behar, Ph.D.
Robotic Vehicles Group
NASA/Jet Propulsion Laboratory
Pasadena, California

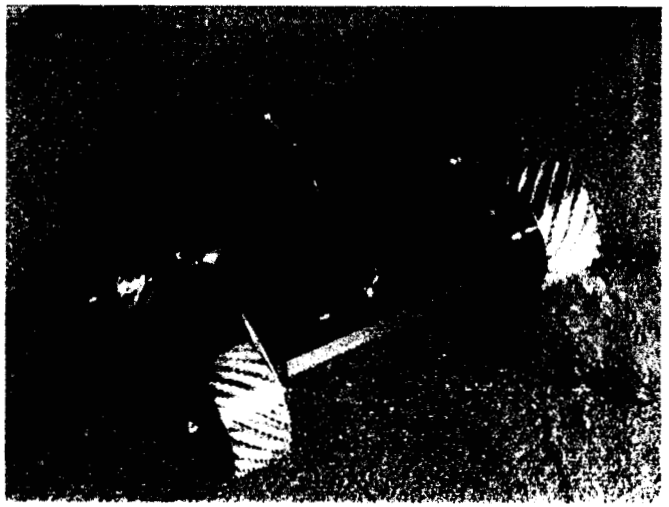
Introduction

- Overview of Diverse Robotics Research Projects
- Points to Remember
  - Early Stages of Evolution
  - Iterative Loop Engineering
  - Simple is Key

Topics of Discussion

- MUSES-CN Asteroid Rover
- CONRO Reconfigurable Robot
- Europa Cryobot
- Sub-Kilogram Intelligent Telerobots
- Autonomous Flying Vehicles
- Others

MUSES-CN APS Rover



Ongoing and future research activities:

•Micro miniature gear motors that will operate under harsh thermal and vacuum conditions of likely nanorover missions

•solar panel dust sensing and control techniques

•techniques for electrostatic sensing of wheel-terrain contact and proximity

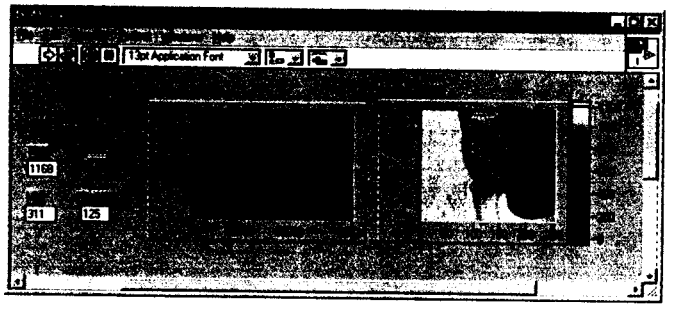
•motion behaviors that exploit the high mobility characteristics of the posable-strut chassis in performing hazard avoidance and long-range navigation

•a computing architecture based on a real-time operating system running on a 32-bit, radiation-hardened, embedded computer

•control approaches to mobility on small bodies (asteroids/comets)

•a new computing architecture to support further levels of miniaturization over the current prototype.

MUSES-CN APS Camera Module

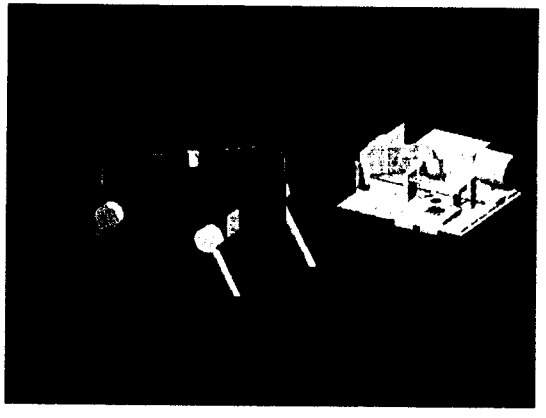


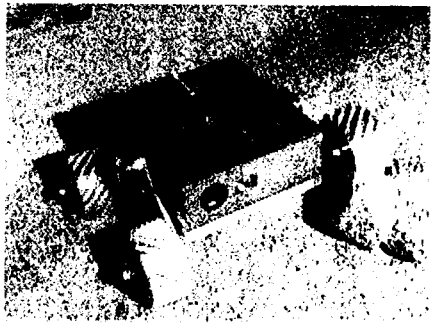
Features:

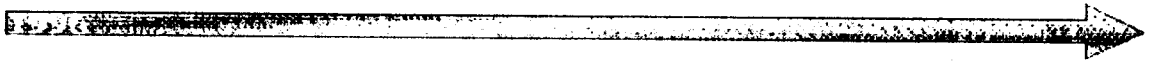
- •X-Y addressability - small 5 pixel size (10um)
- •Low noise (5e- r.m.s., single read)
- •High dynamic range (80 dB)
- •Good quantum efficiency (25% peak photogate mode, 50% peak photodiode mode)
- •Large formats (up to 1K x 1K demonstrated)
- •Single +5 volt (or +3 volt) power supply operation
- •High Speed Electronic shutter (<100usec. exposure)
- •Great Anti-blooming (10^4 x saturation)
- •No image lag >80db suppression
- •On-chip timing, control, signal chain electronics
- •Low Power (e.g. 10mW at 1M pixels/sec; includes ADC)
- •Radiation resistant compared to CCDs

NASA CSMT JPL

MUSES-CN Rover Evolution

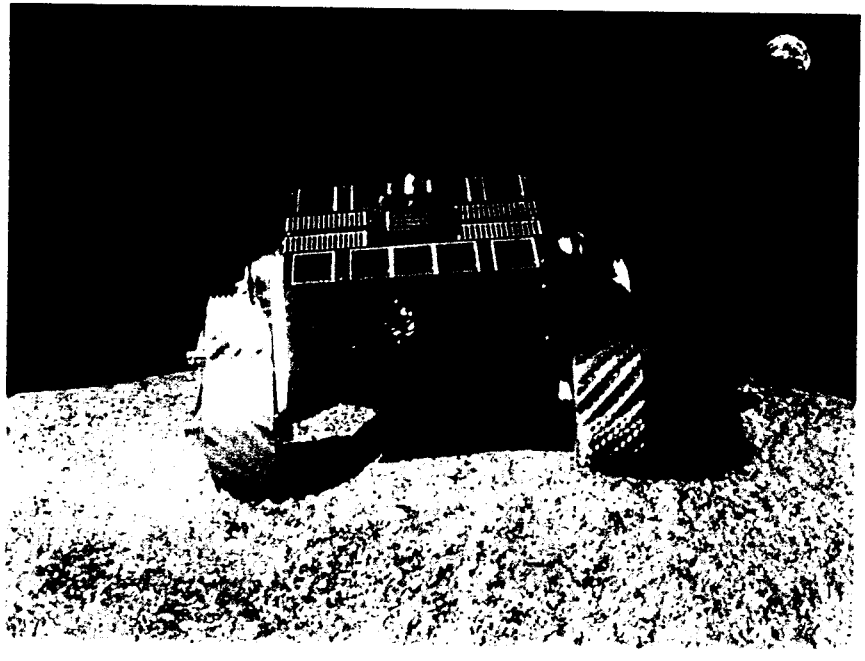


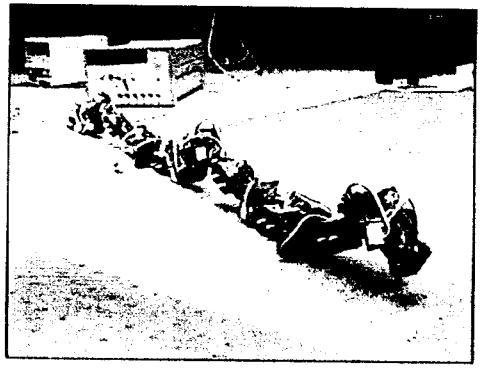




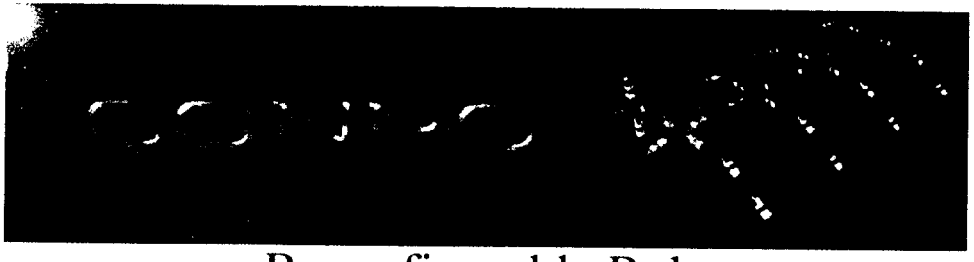
MUSES-CN Rover

Field Tests





CONRO Snake



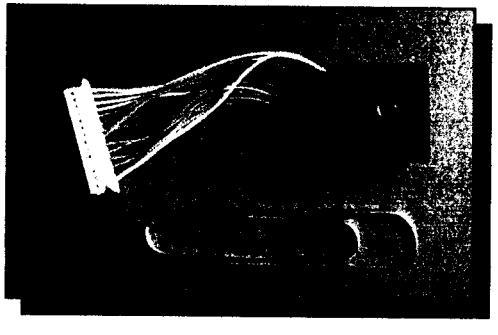
Reconfigurable Robots

CONRO hexapods

Where are we going...

- Software to control the robots
- Automatic reconfiguration
- Custom-made low-profile motor

•Miniature camera



Peter Will, PI, (will@isi.edu)
Wei-Min Shen, co-PI, (shen@isi.edu)

Research Staff:
Andrés Castaño, Bob Kovac, Nestoras Tzartzanis,
Alberto Behar, Berokh Khoshnevis

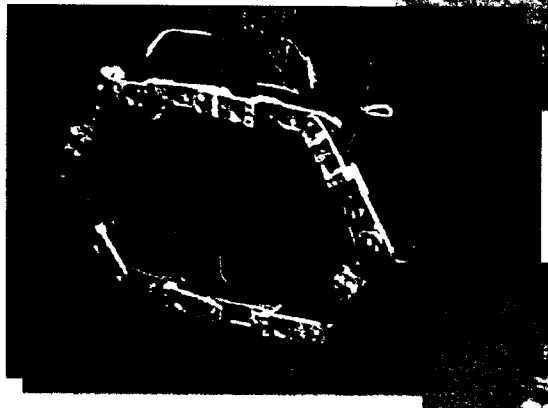
Graduate Research Assistants:
Ramesh Chokkalingam, Marcos Ferretti, Benham Salemi

http://www.isi.edu/conro

USC/ Information Sciences Institute
4676 Admiralty Way
Marina del Rey, CA 90292
phone 310-822-1511, fax 310-822-6592

Prototype 1

Rolling loop

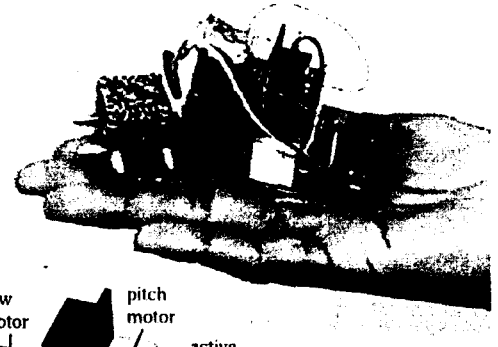


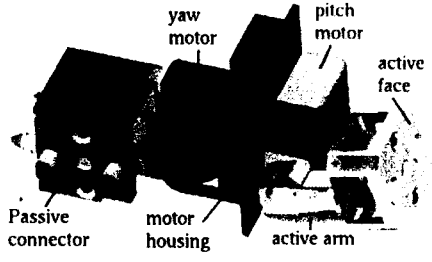
Traveling wave

Metamorphing

Hexapod

Prototype 2





CONRO module

Processor and logic:
- Parallax Stamp II (Pic16C57, 2K EEPROM, 16 I/O ports)
- 8-bit ADC (8 channels)
- I/O multiplexer

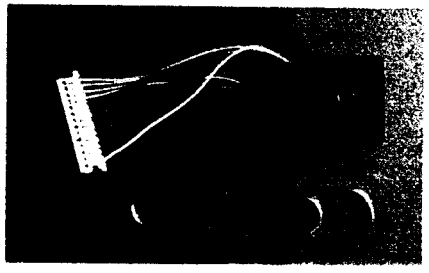
Communication :
- IR-based serial communication with/out flow control

Sensors:
- 4 IR receivers
- IR RX-TX pair can work as proximity sensor
- Motor feedback signals (proportional to generated force)

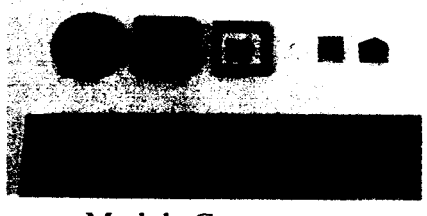
Actuators:
- 2 RC servos (yaw and pitch DOF)
- SMA actuator for module disengagement

Power:
- 6v low voltage - high current node (160 mA/h)
- 9v high voltage - low current node (320 mA/h max)
- Power consumption: 300mW(idle), 1.8W(motor or SMA)

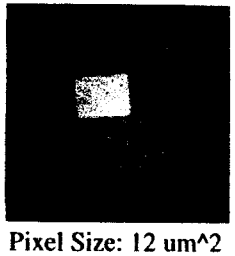
CONRO Camera Module



Dim: Brd 17 mm^2
Depth 15 mm w/ lens



Module Components



Pixel Size: 12 um^2
Array: 1.9 x 1.4 mm

Camera Stats:

* Image 164x124 pixels, 8bit Res.
* Frame Rate: 30 fps w/10mhz clk
* Field of View: ~12 deg
* Power: 12 mA at 5V, 60 mW
* S/N: 36 db (Typ.)
* Exposure Control: 25000:1
* Min. Illumination: 0.1 Lux
* On Chip 8-bit A/D Converter
* Auto Gain & Black Level Calib
* Options selectable via serial int.
* Color option available
* Simple Interface:
  8 data, gnd, vcc, Fram strt
  pix val, ser dat, ser clk

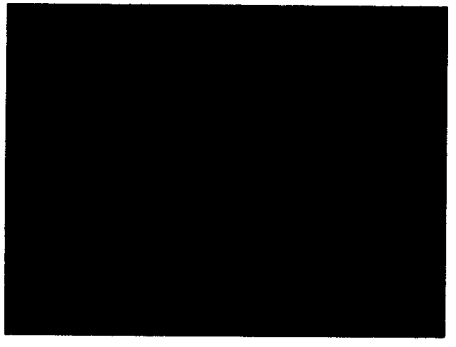
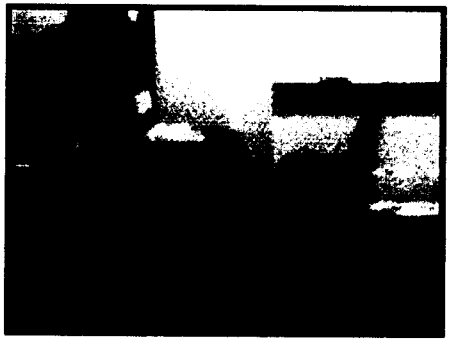


Chart is 50" away, 11" wide



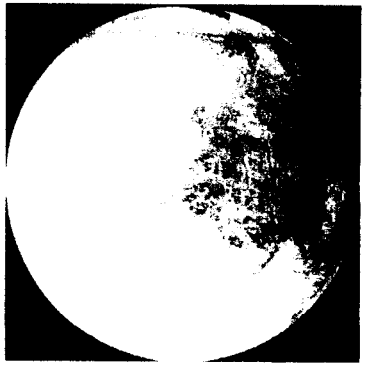
Sample Office View

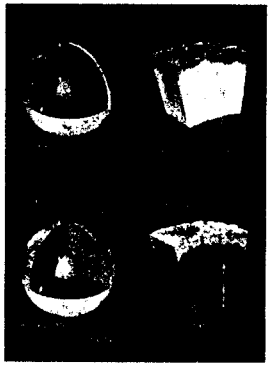
Europa Cryobot

- Proposed ice-penetrating Cryobot and Hydrobot to explore the ice-covered ocean on Jupiter's large satellite, Europa

- Cryobot would melt through the ice cover and deploy a hydrobot, a self-propelled underwater vehicle to analyze the chemical composition of the ice/water in a search for signs of life.

- Related Projects
  - Lo'ihi Hydrothermal Vent Probe
  - Antarctic Ice Borehole Probe





Lo'ihi Hydrothermal Vent Probe

PASADENA STAR-NEWS THURSDAY, AUGUST 27, 1998

FRONT PAGE

JPL probe's mission: Seek life

Device to hunt under water and in outer space

By Andrew Bridges
STAFF WRITER

LA CANADA FLINTRIDGE - Building on an experiment that will end Friday in a kelp-filled Southern California aquarium, JPL scientists hope to fine-tune a probe that one day will look for life on one of Jupiter's moons.

For the time being, the instrument-laden device will focus on finding life in one of the Earth's most inhospitable spots: a mile beneath the surface of the Pacific, amid volcanic vents that belch super-heated water in total darkness.

The idea behind studying space is to understand the world "our home," said Lloyd French, project lead and system architect for the experiment.

The probe had its first workout this month in the Monterey Bay Aquarium. There, Jet Propulsion Laboratory researchers spent the past two weeks conducting comparatively cheap and problem-free engineering tests in the tourist hot spot's kelp forest, amid tiger sharks and star fish.

20 miles off the island of Hawaii and will descend 4,250 feet beneath the surface.

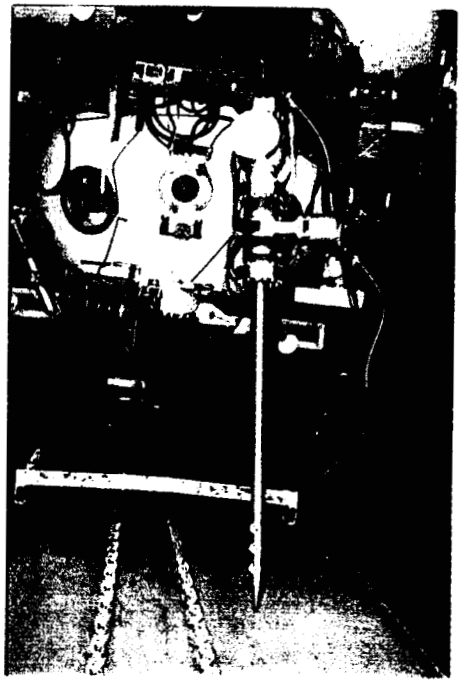
The area around the vents, which were recently discovered, is host to a thin, gelatinous veil of living bacteria despite temperatures inside the vents that approach 350 degrees.

"If we can find bacteria inside the vents, it would start the process of detailing new temperatures at which life can exist," said Gimbi French, system's engineer for data acquisition for the project and wife of Lloyd French.

Life has not been

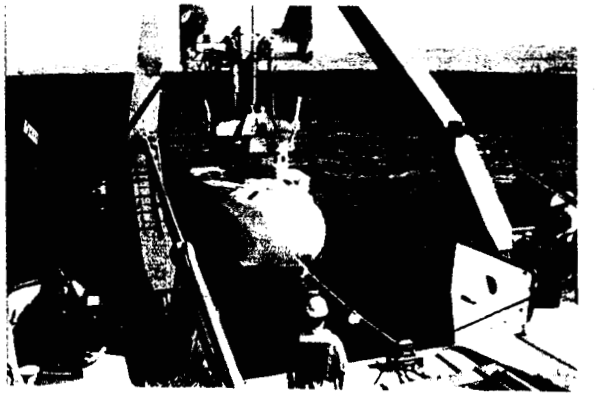
SPACE SCIENTISTS' search for life elsewhere in the solar system is bringing them to the giant kelp forest exhibit at the Monterey Bay Aquarium to test a new probe that might one day look for life on one of Jupiter's moons.

Purpose:
investigate the possible presence of a thin, jelly-like biomass that has been observed near or in the vents, located at the summit of the Lo`ihi seamount, an underwater Hawaiian volcano



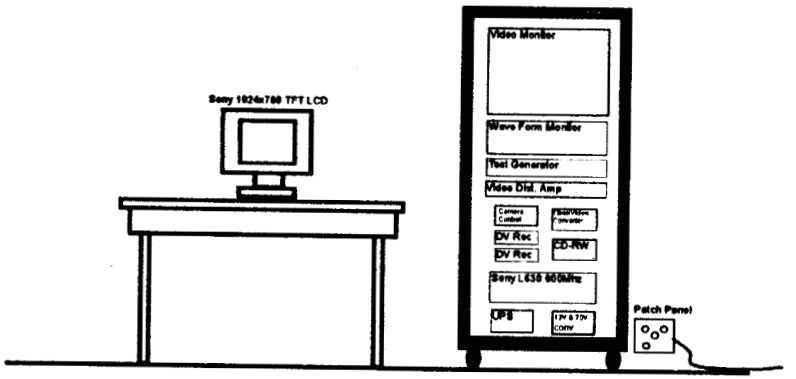
Tasks:
- Placed a probe in underwater volcanic vent
- Recorded images of the material in vent

- To determine the implications of those images, in terms of the temperature range at which life is sustainable

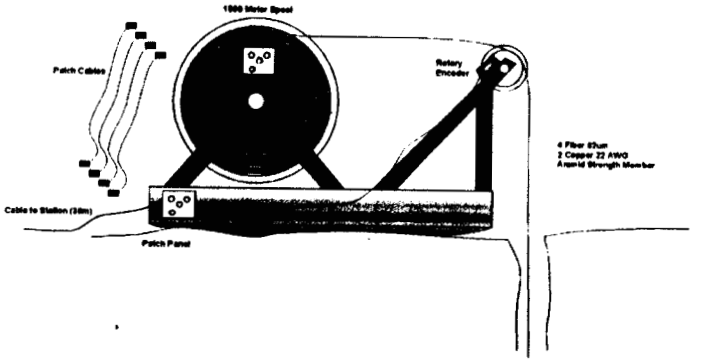


Antarctic Ice Borehole Probe

Base-Line Ground Station



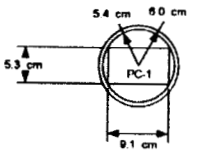
Base-Line Tether Design

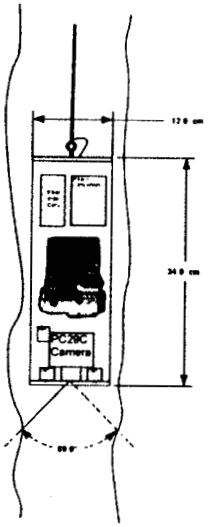


Focus:
Serves as a stepping-stone in technology development to demonstrate the capability and instrumentation packaging needed for work in extreme ice/liquid-type environments

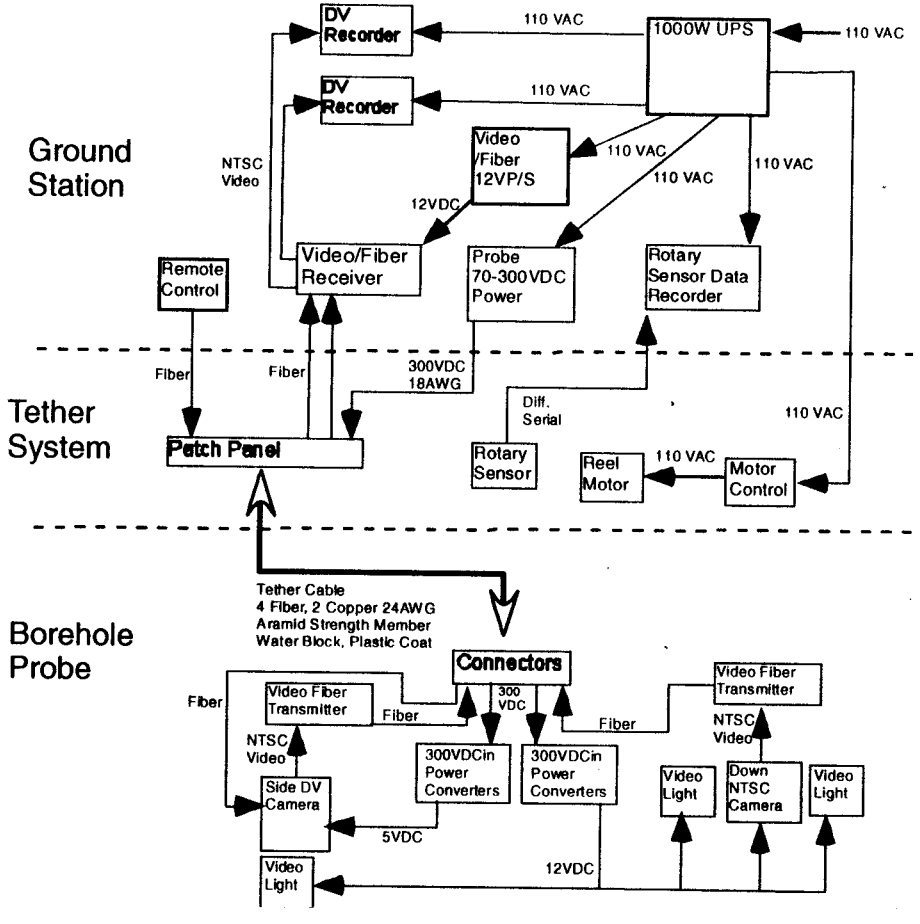
Results:
information gathered could aid in future terrestrial and extraterrestrial missions that require exploration in ice/liquid environments, including missions to sub-glacial lakes, Lake Vostok in Antarctica, Mars Polar Caps and Jupiter's moon, Europa

Base-line Two Camera Probe





Ice Borehole Probe System



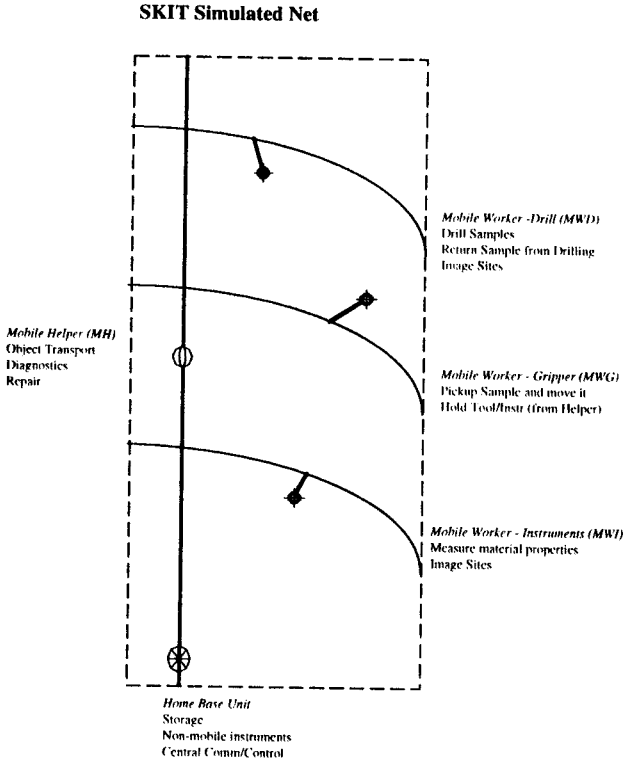
Sub-Kilogram Intelligent Tele-robots

PhD Thesis motivated by the desire to create an evaluation methodology for multi-agent exploratory systems

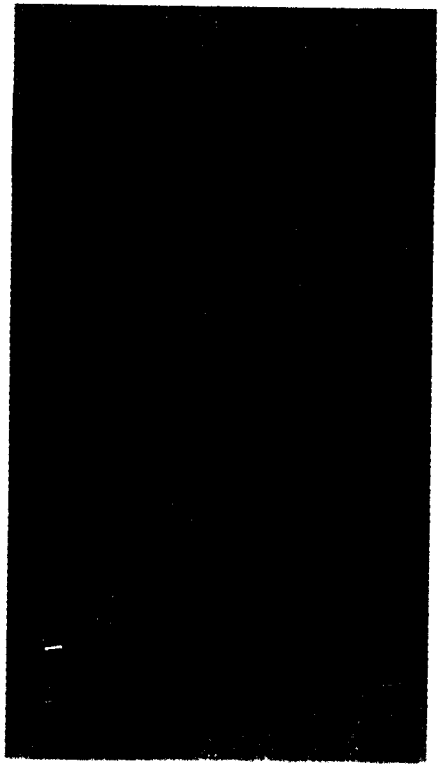
Created an environment scenario in which we can devise experiments to test the effects of different parameters on an exploration colony in an effort to obtain a measure of colony performance

Scenario: Exploration of an asteroids surface using a sub-kilogram robot colony

SKIT Colony Hardware Demonstration

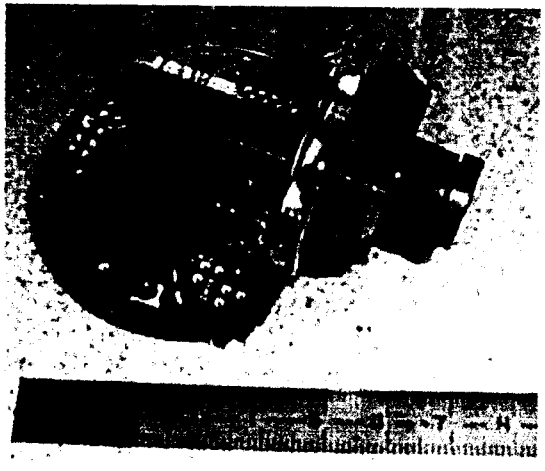


SKIT demonstration showing
3 workers and 1 helper



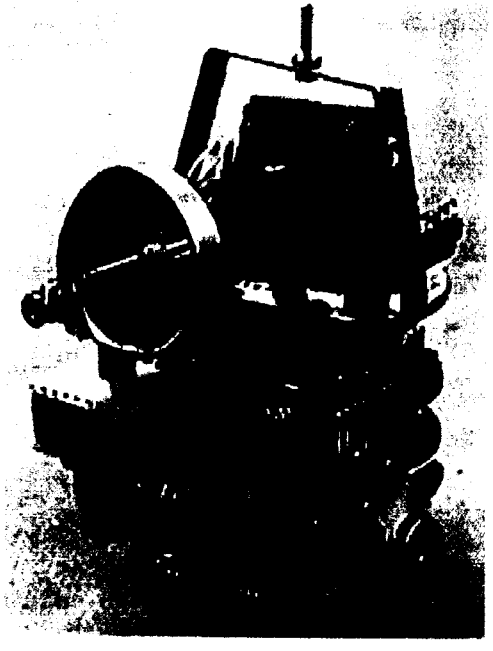
Tether Design

SKIT Robot Vision Processor

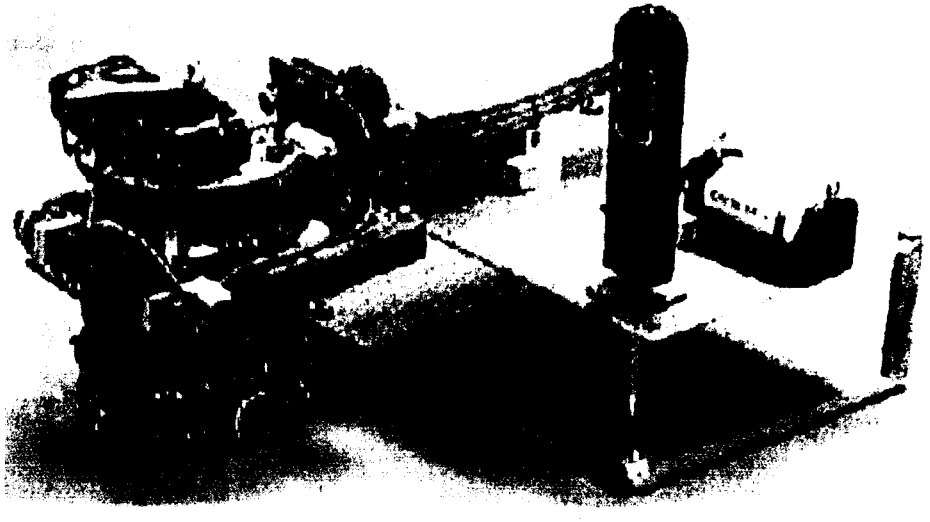


CMOS Image Sensor with DSP Processor

Sub-Kilogram Intelligent Tele-robots



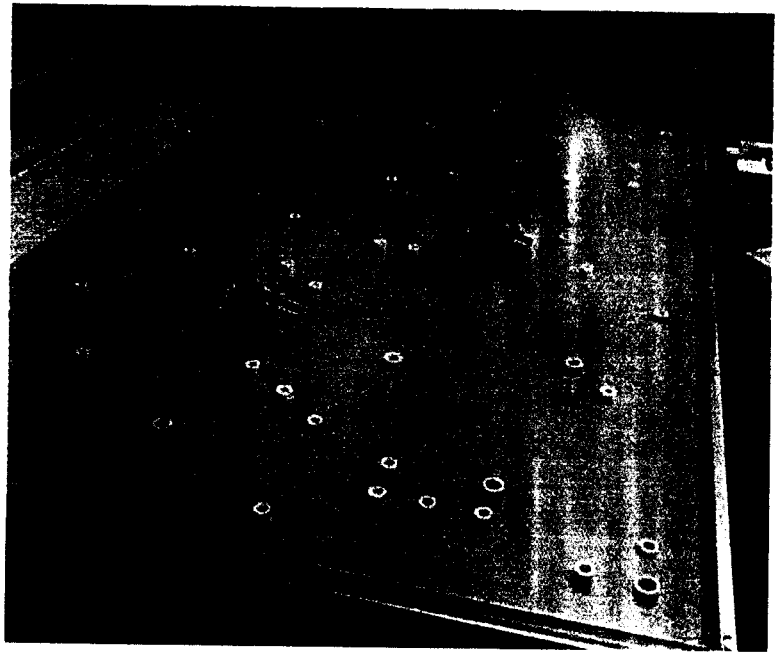
Mobile Worker Instruments



Mobile Helper

Sub-Kilogram Intelligent Tele-robots Demonstration
Space Studies Institute Conference on Space Manufacturing 11
May 10th, 1997 Princeton NJ

SKIT Colony Hardware Experiments

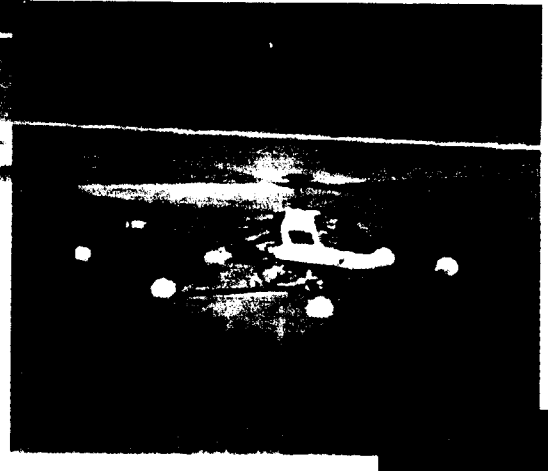


SKIT Hardware Experiments

Sample and Obstacle detectors

AFV Autonomous Flying Vehicle

- Air Vehicle is equipped with 14 sensors
- Uses Model Helicopter as Airframe



Control System designed to:

- Remain in stable flight
- Navigate to a target
- Manipulate a physical target

Challenge:

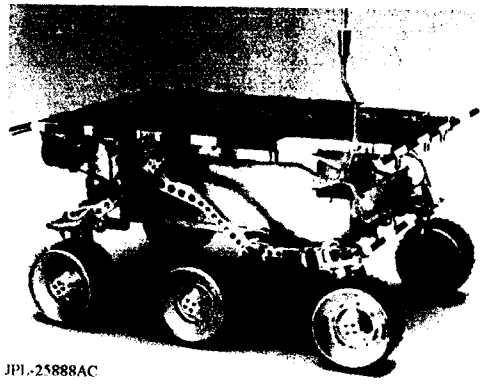
Unlike terrestrial mobile robots, the craft must constantly make sound decisions to maintain its integrity

Historical Robots

Go-For

MUSES Rover

Rocky 4



JPL-25888AC

Sojourner

What This Means

- Points to Remember
  - Robotics is expanding into diverse unforeseen, exciting areas
  - Early Stages of Development
  - Lots of Trial and Error
  - Elegance is your best friend

Next Steps

- Go forth and build!!!!!!